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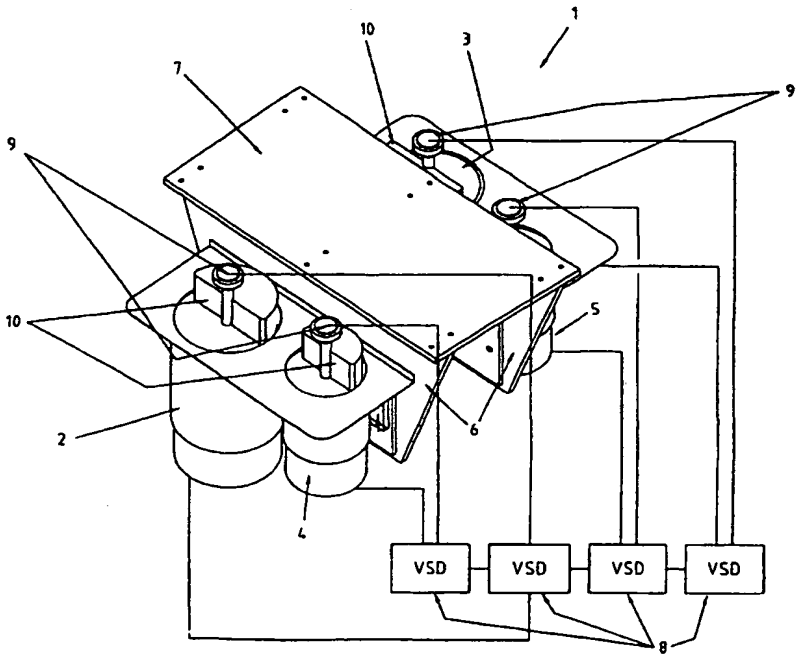
(54) Title: DRIVE MECHANISM FOR VIBRATORY CONVEYOR SYSTEM

(57) Abstract

A mechanism for driving a vibratory–type conveyor system which relies on the known principles of superimposition of simple harmonic oscillating forces, but enables the operation of such a system in the absence of mechanical interconnection of vibrator motors. A drive unit of the mechanism includes at least two pairs of vibrators motor (2, 3, 4, 5), each pair adapted to produce an oscillating force at a selected frequency, and electronic control means (8) adapted to control operation of the motors so that the forces of each pair of motors superimpose to produce a net driving force to product in or on vibrator equipment in a selected direction. The vibrator motors are preferably eccentric weighted (10) rotary vibrator motors, and the electronic control means enables variable control of individual motor speeds and/or the positional rotation of the weights (10) of the motors. The invention also relates to the use of multiple drive units on a common piece of vibratory equipment, wherein electronic means are provided to enable synchronisation of the control of each drive unit to provide a common driving force in a selected direction.



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DRIVE MECHANISM FOR VIBRATORY CONVEYOR SYSTEM

TECHNICAL FIELD

This invention relates to a mechanism for driving a vibratory-type conveyor system.

BACKGROUND

A known system for driving vibratory feeders, conveyors, screens or the like (hereinafter referred to as "vibratory equipment") involves use of the principle of superposition of two simple harmonic oscillating forces. Two equal eccentric rotating masses contra-rotate to produce a low frequency linear simple harmonic oscillating force. A second pair of eccentric rotating masses contra-rotate to produce a second linear simple harmonic oscillating force at a frequency twice that of the first pair. By superimposing these two forces so that the peaks in the positive direction coincide, the sum of the forces results in a high magnitude force for a short duration (as represented in Figure 1). The combined forces in the opposing direction create a low magnitude force sustained over an extended period.

The resulting physical motion created is fast in one direction and slow in the other. For this motion to be effective in conveying product along vibratory equipment the force in the forward direction must be less than the threshold required to overcome the friction between the conveyor surface and the product. Forces in the reverse direction need to be greater than the threshold required to overcome friction between the conveyor surface and the product, so that the product will continue forward under its own momentum when the conveyor moves back quickly in the reverse direction.

Conventional systems that employ this principle involve the four eccentric rotating masses mechanically interlinked through a gearbox or timing belt/chain

arrangement and driven by a single motor or timing belt/chain. The mechanical linkage provides for the required co-ordinated operation of the masses to produce the required forces.

This mechanical co-ordination provides for significant limitations to such a drive unit.

The gear box arrangement limits the drive unit to a particular size and configuration of eccentric rotating masses. Such a unit will operate effectively for a conveyor of given dimensions and under a given load. If those conditions vary significantly the unit will not operate optimally or will need to be replaced with a different unit.

It is not possible to adjust the operating frequency of a mechanically-linked unit while the unit is operating. It may also not be possible to adjust the amplitude of the forces since the flyweights may be fixed. And the magnitude of the combined forces and the ratio of forces between the two pairs of eccentric rotating masses cannot be easily adjusted.

A given mechanically-linked drive unit has the capacity to drive a conveyor of defined dimensions (in terms of length and cross-section) and capacity. If a longer conveyor is required it is not practical to synchronise multiple mechanically-co-ordinated drive units. Thus, conveying product over longer distances can only be achieved by having multiple conveyors, each driven by its own drive unit, sequentially feeding one into or onto the next. Each consecutive conveyor must be slightly lower than the preceding conveyor to enable the required transfer of product through the system. This involves inefficiencies both in terms of the need to raise product to the starting height and the need to have the required height space.

Reversing the direction of drive of a conventional mechanically-linked drive unit is complex or impractical.

It is an object of the present invention to provide a drive mechanism for vibratory equipment which reduces or overcomes the abovementioned problems or which at least provides the public with a useful alternative.

Other objects of the invention may become apparent from the following description which is given by way of example only.

SUMMARY OF THE INVENTION

According to one aspect of the present invention there is provided a drive unit adapted to drive vibratory equipment, said unit including at least two pairs of vibrator motors each pair adapted to produce an oscillating force at a selected frequency and electronic control means adapted to control operation of the motors so that the forces of each pair of motors superimpose to produce a net driving force to product in or on the vibratory equipment in a selected direction.

In one preferred form of unit of the present invention the control means may include interlinking of the vibrator motors by electronic feedback means, with each motor connected to a corresponding variable speed drive controller, and a rotary encoder associated with each motor.

Preferably, one drive controller is a master controller and the remaining drive controllers are slave controllers.

Preferably, the vibrator motors may be eccentric weighted rotary vibrator motors.

Preferably, the electronic control means may be adapted to control the selected frequencies by adjusting vibrator motor speeds.

Preferably, the electronic control means may also be adapted to control synchronisation of positional rotation of the weights of the motors.

In a further preferred form of drive unit of the present invention there may be two pairs of eccentric weighted rotary vibrator motors.

Preferably, the control means may be adapted to maintain a speed ratio between the two pairs of motors of substantially 2:1.

Preferably, the control means may be adapted to maintain a force ratio, determined by the relative rotational positioning of the weights of the motors, substantially within the range 1:1 to 3:1.

Preferably, the control means may be adapted to reverse the selected direction by switching from a first reference point to a second reference point for the encoders.

According to a further aspect of the present invention there is provided a vibratory equipment drive system, said system including: a plurality of drive units each connected to a common piece of vibratory equipment or conveyor, and each drive unit including at least two pairs of vibrator motors, each pair adapted to produce an oscillating force at a selected frequency, and electronic control means adapted to control operation of the motors so that the forces of each pair of motors superimpose to produce a net driving force to product in or on the vibratory equipment in a selected direction; and electronic synchronisation means adapted to synchronise operation of the plurality of drive units via their control means so that each drive unit acts simultaneously to provide a common force in the selected direction.

According to a further aspect of the present invention th re is provided a vibratory equipment drive system, said system including a plurality of drive units, each drive unit as hereinbefore described, and electronic synchronisation means adapted to synchronise operation of the plurality of drive units via their control means.

According to a further aspect of the present invention there is provided a method of transporting a product along a conveyor by vibratory means the method including the steps of:

- operating a drive unit connected to the conveyor, the unit including at least two pairs of vibrator motors, each pair adapted to produce an oscillating force at a selected frequency; and
- controlling operation of the drive unit by electronic control means adapted to control the net driving force to product in or on the conveyor in a selected direction.

Preferably, the method may include control of the vibrator motor speeds and/or positional rotation of the weights of eccentric weighted rotary vibrator motors.

Preferably, the method may include operating a plurality of drive units each connected to the conveyor, and synchronising the control of the drive units to provide a common drive force in the selected direction.

Other aspects of the present invention may become apparent from the following description which is given by way of example only and with reference to the following drawings.

BRIEF DESCRIPTION OF DRAWINGS

Figure 1:
Shows the super-imposition of forces produced by two pairs of rotary vibrator motors;

Figure 2:
Shows a perspective view of a drive unit of the present invention in one preferred form, with the control means shown schematically;

Figure 3:
Shows a circuit diagram of a control means employed in a drive unit of the present invention;

Figure 4:
Shows a perspective view of a vibratory equipment drive system of the present invention with three drive units adapted to operate in harmony.

Figure 5:
Shows a side view of the system of Figure 4 with the control means represented schematically.

DETAILED DESCRIPTION OF THE INVENTION

The present invention relates to apparatus to enable synchronisation of vibrator motors for driving vibratory equipment without the need for mechanical linking, and the ability to drive vibratory equipment of substantially indefinite length by synchronising the forces supplied by multiple drive units.

Figure 2 shows a drive unit 1. The unit includes four vibratory motors, including a first pair 2, 3 and a second pair 4, 5. The motors are secured to brackets 6 in a common orientation. A drive plate 7 is provided for connection to the vibratory equipment (not shown). Control means 8 are associated with each motor.

It will be appreciated that in a drive unit of the present invention each of the vibratory motors 2, 3, 4, 5, is physically independent. Thus, standard eccentric weighted vibratory motors may be used, and pairs of motors may be selected and changed, as necessary, to meet required conditions. For example, a more powerful drive unit will be required to drive larger vibratory equipment and products of different types. The mechanism of operation of a given motor will be well known to a person skilled in the art, as will the principles underlying a dual motion linear vibration system.

The vibratory motors may be mounted in either the vertical or horizontal plane, although it will be appreciated that each pair of motors will be mounted in the same plane.

Associated with each motor 2, 3, 4, 5, is a controller 8. Rotary encoders 9 associated with each motor provide data to their corresponding controller 8 about the speed and orientation of the weights 10 of that motor.

A circuit diagram of a drive unit of the invention, in one preferred form is shown in Figure 3.

The controllers 8 are configured in such a manner that a master controller 11 governs the actions of the other three slave controllers 12. That master controller 11 governs a master motor 13 and the other three controllers 12 therefore govern slave motors 14. The electronic linking of the motors enables specific degree alignment and

positioning orientation of the eccentric weights of the motors, and maintenance of these relational positions during operation.

The operating effect of the four controlled motors achieves asymmetric vibration to provide a driving moment to a product on the vibratory equipment which may be any form of feeder, conveyor, screen, tube or the like along which product needs to be conveyed from one point to another.

Each pair of motors counter-rotate in either direction with a speed ratio between the pairs. The preferred ratio is 2:1 and the controllers may be programmed to maintain this optimum speed ratio. Thus, adjustment of the speed of the master motor would automatically cause adjustment of the slave motors to the required new rate. The speed ratio would be adjustable during operation to optimise the drive.

The speed of the motors may be adjusted (whilst maintaining the preferred ratio) to optimise the nature of the harmonic oscillating forces for any given product. In this respect, the speed and timing of the reverse movement of the conveyor must be adjusted so that the forces in the reverse movement are greater than the threshold required to overcome friction between the conveyor surface and the product, for that particular product.

Furthermore, the controllers also enable adjustment of the motor flyweight orientation to increase the amplitude and optimise performance. The magnitude of the combined force resulting from the vibratory action, and the ratio of forces between the two pairs of motors, can therefore be adjusted by the controllers. A preferred force ratio is between 1:1 and 3:1, and again the controllers may be programmed to maintain a selected force ratio.

Reversal of product flow is achieved by simply switching between two reference points in the encoders of the motors. The new reference points will cause

the first pair of motors to rotate through 180° in relation to the second pair of motors, and then maintain this new relationship. It will be appreciated that the controllers may be pre-programmed with the two reference points, and that direction reversal is substantially instantaneous since there is no need to change the direction of rotation of the motors.

The electronic control of the motors within a drive unit can be extended to cover the synchronisation of multiple drive units to produce a vibratory equipment drive system. This is shown, for example, in Figures 4 and 5. Each drive unit 20 is positioned beneath the vibratory equipment (conveyor) 21 and has its own associated control means 22. There is a master controller and motor and three slave controllers and motors in each unit. Electronic means are provided to synchronise the master controllers, so that each unit acts simultaneously to provide a common force on the conveyor in a common direction. Thus, for example, there may be synchronisation of the control of the speed of corresponding pairs of vibrator motors, and of the positional rotation of weights of corresponding motors in each drive unit.

The vibratory forces created are unidirectional allowing for easy isolation from the support structure using simple long pendulums or other devices permitting free longitudinal movement. Lateral and vertical directional movement is minimal. Thus, transmitted vibration in these directions will also be minimal. Transmitted vibration to the support structures 23 will be small and is predicted to be less than 0.05% of the excitation forces.

This enables drive units of the present invention to be employed to drive much longer vibratory equipment than has conventionally been possible. Vibratory equipment of much greater length can therefore be driven, irrespective of the cross-section or the weight of the equipment and product.

Whilst the invention is described with specific reference to a drive unit including two pairs of motors it will be appreciated by a person skilled in the art that additional properties and or improved driving force may be achievable by the inclusion of additional pairs of motors.

Thus, the apparatus of the present invention enables the driving of vibratory equipment in a manner which eliminates the need for gearboxes or other mechanical drive systems. It relies on the use of readily available standard vibrator motors and enables the selection of particular combinations of motors to suit specific circumstances. The combined forces produced by a drive unit of the present invention are adjustable in both magnitude and frequency to allow optimisation of any combination of product and conveyor construction. The operating frequency is adjustable during operation to optimise drive. In addition, total eccentricity of motor flyweights may be adjusted to optimise the combined force and ratio of forces between the motors. Directional drive may be reversed almost instantaneously. And multiple drive units may be synchronised to provide a co-ordinated drive on much longer vibratory equipment than had previously been practical or possible.

Where in the foregoing description reference has been made to specific components or integers of the invention having known equivalents then such equivalents are herein incorporated as if individually set forth.

Although this invention has been described by way of example and with reference to possible embodiments thereof it is to be understood that modifications or improvements may be made thereto without departing from the scope or spirit of the invention.

CLAIMS

1. A drive unit adapted to drive vibratory equipment, the unit including at least two pairs of vibrator motors, each pair adapted to produce an oscillating force at a selected frequency, and electronic control means adapted to control operation of the motors so that the forces of each pair of motors superimpose to produce a net driving force to product in or on the vibratory equipment in a selected direction.

2. A drive unit according to claim 1 wherein the control means includes interlinking of the vibrator motors by electronic feedback means, with each motor connected to a corresponding variable speed drive controller, and a rotary encoder associated with each motor.

3. A drive unit according to claim 2 wherein one drive controller is a master controller and the remaining drive controllers are slave controllers.

4. A drive unit according to any one of claims 1 to 3 wherein the vibrator motors are eccentric weighted rotary vibrator motors.

5. A drive unit according to claim 4 wherein the control means is adapted to control the selected frequency by adjusting vibrator motor speeds.

6. A drive unit according to claim 5 wherein the control means is further adapted to control synchronisation of positional rotation of the weights of the motors.

7. A drive unit according to any one of claims 4 to 6 including two pairs of eccentric weighted rotary vibrator motors.

8. A drive unit according to claim 7 wherein the control means is adapted to maintain a speed ratio between the two motors of substantially 2:1.

9. A drive unit according to claim 8 wherein the control means is further adapted to maintain a force ratio, determined by the relative rotational positioning of the weights of the motors, substantially within the range 1:1 to 3:1.

10. A drive unit according to any one of claims 2 to 9 wherein the control means is adapted to reverse the selected direction by switching from a first reference point to a second reference point for the encoders.

11. A vibratory equipment drive system, the system including: a plurality of drive units each connected to a common piece of vibratory equipment or conveyor, and each drive unit including at least two pairs of vibrator motors, each pair adapted to produce an oscillating force at a selected frequency, and electronic control means adapted to control operation of the motors so that the forces of each pair of motors superimpose to produce a net driving force to product in or on the vibratory equipment in a selected direction; and electronic synchronisation means adapted to synchronise operation of the plurality of drive units via their control means so that each drive unit acts simultaneously to provide a common force in a selected direction.

12. A vibratory equipment drive system including a plurality of drive units of any one of claims 1 to 10, each drive unit connected to a common piece of vibratory equipment or conveyor, and electronic synchronisation means adapted to synchronise operation of the plurality of drive units via their control means.

13. A vibratory equipment drive system according to claim 12 wherein the electronic synchronisation means is adapted to synchronise the vibrator motor speeds of corresponding motors in each drive unit.

14. A vibratory equipment drive system according to claim 13 wherein the synchronisation means is further adapted to synchronise positional rotation of the weights of corresponding motors in each drive unit.

15. A method of transporting a product along a conveyor by vibratory means, the method including the steps of:

- operating a drive unit connected to the conveyor, the unit including at least two pairs of vibrator motors, each pair adapted to produce an oscillating force at a selected frequency; and

- controlling operation of the motors by electronic means so that the forces of each pair of motors superimpose to produce a net driving force to product in or on the conveyor in a selected direction.

16. A method of transporting product according to claim 15 wherein the control step includes controlling the selected frequency by adjusting vibrator motor speeds.

17. A method of transporting product according to claim 16 wherein the vibrator motors are eccentric weighted rotary vibrator motors and the control step further includes synchronisation of positional rotation of the weights of the motors.

18. A method of transporting product according to claim 17 wherein the drive unit includes two pairs of eccentric weighted rotary vibrator motors and a speed ratio between the two pairs of motors is controlled at a ratio of substantially 2:1.

19. A method of transporting product according to claim 18 wherein a force ratio, determined by the relative rotational positioning of the weights of the motors, is controlled substantially within the range 1:1 to 3:1.

20. A method of transporting product according to any one of claims 15 to 19 including a plurality of drive units each connected to the conveyor, and the method further including the step of synchronising by electronic means the control of each drive unit so that each unit provides a common drive force in the selected direction.

21. A method of transporting product according to claim 20 wherein the vibrator motor speeds of corresponding motors in each drive unit are synchronised.

22. A method of transporting product according to claim 21 wherein the positional rotation of weights of corresponding motors in each drive unit are synchronised.

23. A drive unit adapted to drive vibratory equipment, substantially as herein described and with reference to the accompany drawings.

24. A vibratory equipment drive system substantially as herein described and with reference to the accompanying drawings.

25. A method of transporting product along a conveyor, substantially as herein described and with reference to the accompanying drawings.

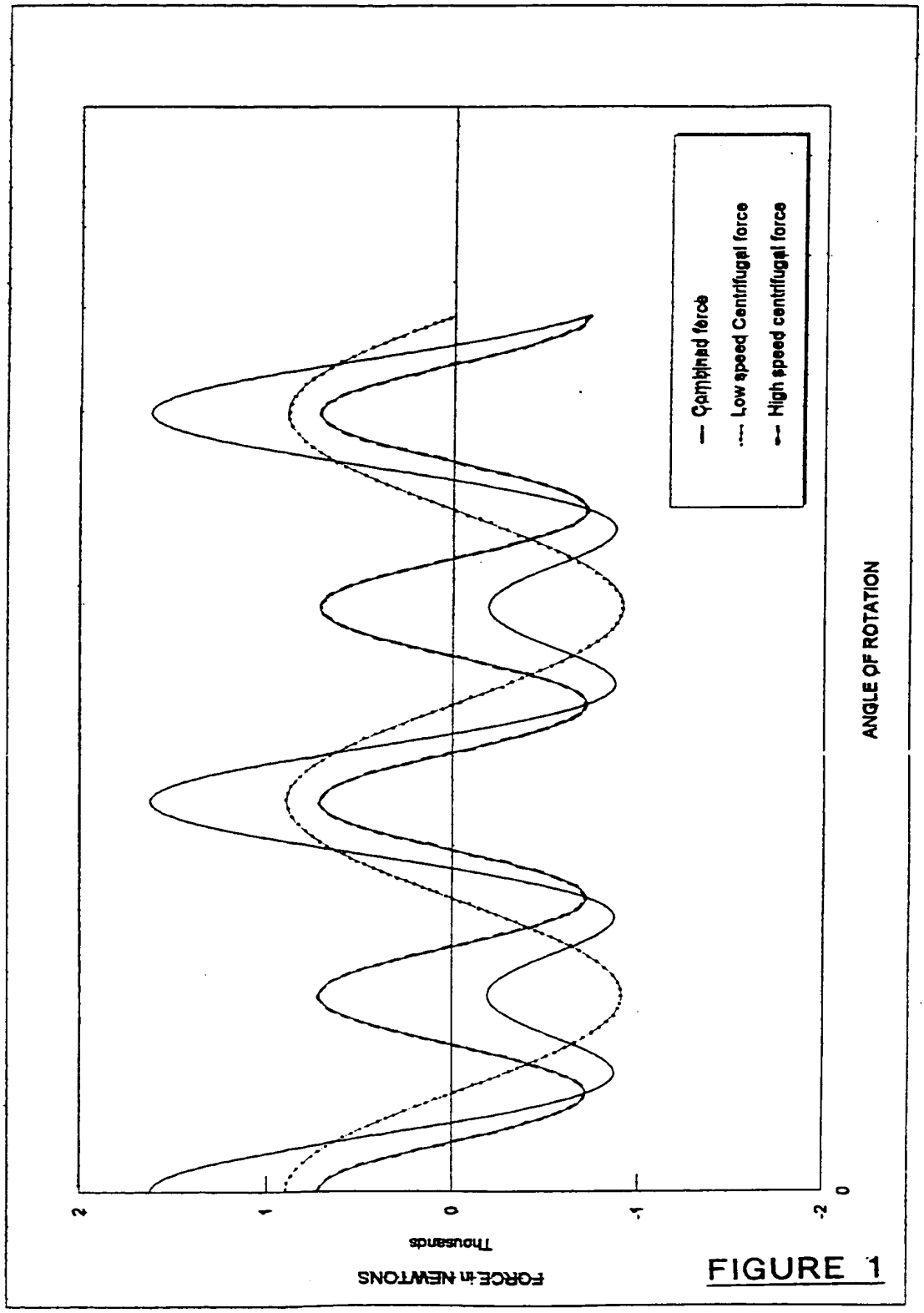

Combined force
Low speed Centrifugal force
High speed centrifugal force
ANGLE OF ROTATION
FORCE in NEWTONS
Thousands
2
1
0
-1
-2
0

FIGURE 1

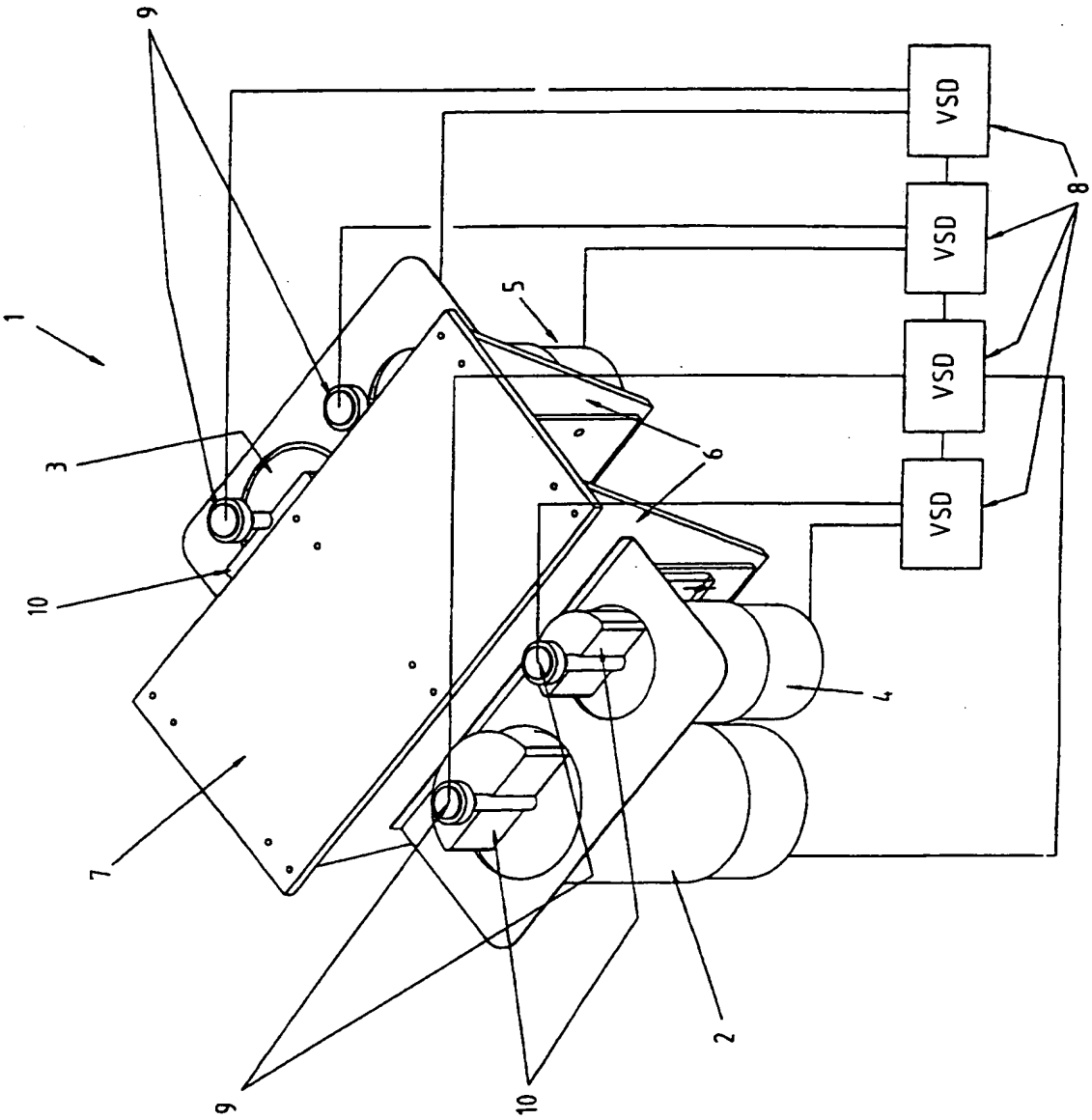
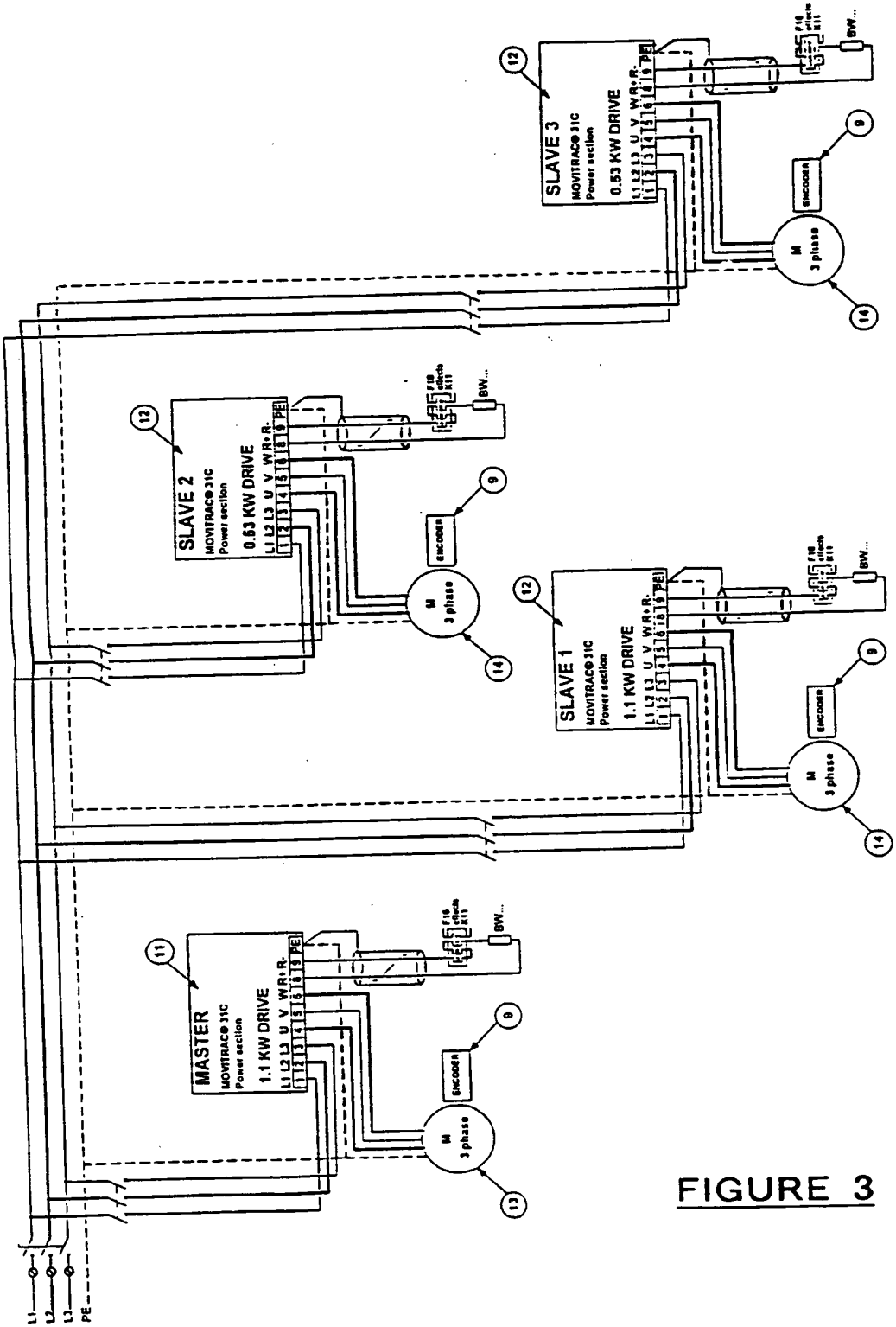


FIGURE 2


SLAVE 3
MOVITRAC® 31C
Power section
0.55 KW DRIVE
SLAVE 2
MOVITRAC® 31C
Power section
0.55 KW DRIVE
SLAVE 1
MOVITRAC® 31C
Power section
1.1 KW DRIVE
MASTER
MOVITRAC® 31C
Power section
1.1 KW DRIVE
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BW...
ENCODER
M
3 phase
L1
L2
L3
PE

FIGURE 3

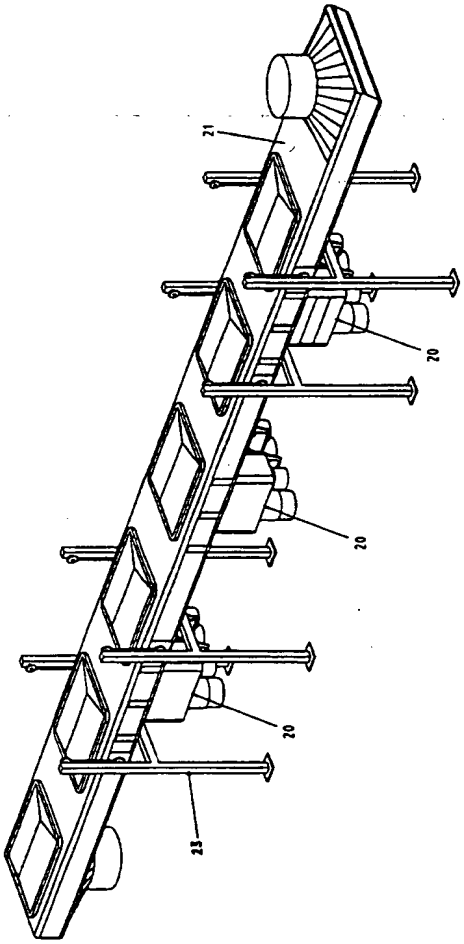

FIGURE 4

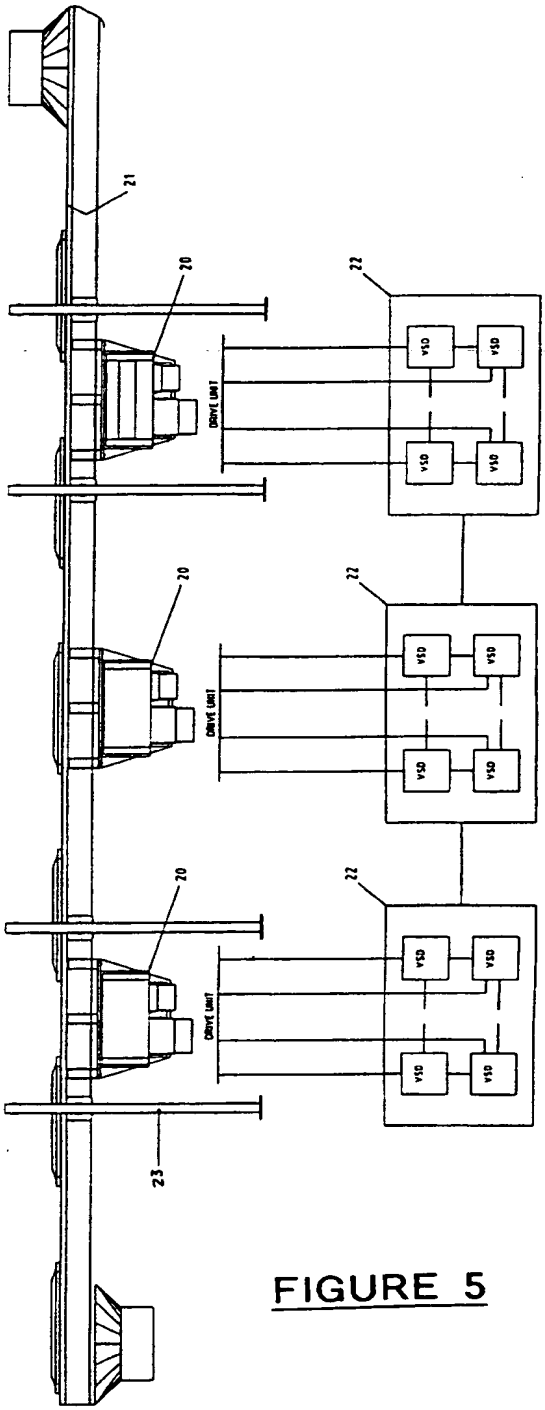

FIGURE 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/NZ 99/00165

A. CLASSIFICATION OF SUBJECT MATTER

Int Cl[6]: B65G 27/20, B06B 1/16

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC: B65G 27/-, B06B 1/-

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AU: B65G 27/20, 27/16, 27/18, 27/10, B06B 1/16

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
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C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5392898 A (BURGESS et al) 28 February 1995 Whole document	1-25
Y	WO 98/31616 A (FMC CORPORATION) 23 July 1998 Whole document - Page 2, lines 25-31, & Page 4, lines 29 to page 5, line 1, Page 6, lines 7-21,	1-25
Y	Patent Abstracts of Japan, JP, 7-285638 A (KIYUU M SOFUTO:KK et al) 31 October 1995 Abstract - Control means for electric motors	1-25

[X] Further documents are listed in the continuation of Box C

[X] See patent family annex

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Date of the actual completion of the international search	Date of mailing of the international search report
21 January 2000	31 JAN 2000

Name and mailing address of the ISA/AU	Authorized officer
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/NZ 99/00165

C (Continuation). **DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P,X	AU 16032/99 A (CARRIER VIBRATING EQUIPMENT) 16 June 1999 Whole document	1-25
A	DE 4106443 A (IME SNC DI ZUCCARIN) 12 December 1991 Abstract and drawings - plurality of vibrating drive units	1-25

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/NZ 99/00165

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Patent Document Cited in Search Report		Patent Family Member					
US	5392898	CA	2192072	EP	764134	JP	10-500383
		WO	95/33673				
WO	98/31616	AU	58178/98	US	5938001		
JP	07-285638	NONE					
AU	16032/99	WO	99/28218				
DE	4106443	IT	1239827				
							END OF ANNEX